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ENVIRONMENTAL CRITERIA DETERMINATION FOR AIR-LAUNCHED TACTICAL PROPULSION SYSTEMS

Part 3. DESCRIPTION OF THE ENVIRONMENT

by

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ABSTRACT. Part 3 defines each environment treated in the stockpile-to-target sequence (Part 1) in general terms. It presents a frame of reference in which the total environment can be discussed by test engineer, designer, and project manager without a communication breakdown due to different interpretations of the subject matter.

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42

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NAVAL WEAPONS CENTER AN ACTIVITY OF THE NAVAL MATERIAL COMMAND

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FOREWORD

This report consists of three parts:

Part 1. Stockpile-to-Target Sequence, which contains the environmental limitations in chart form for easy reference.

Part 2. Technical Support for Stockpile-to-Target Sequence, which discusses each criterion presented in Part 1 and gives the reasoning, technical limitations, and work required in each area.

Part 3. Description of the Environment, which defines the environments treated in Part 1 and details an environmental frame of reference for the test engineer, designer, and project manager.

Part 1 is the part of the report which will be most widely used. Parts 2 and 3 are available as needed to support Part 1.

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CONTENTS

Introduction	1
Chapter 1. Temperature	2
Standard Air Temperature	2
Ordnance Temperatures	2
Low Temperature Regime	4
Temperature Durations	5
Chapter 2. Relative Humidity	7
Chapter 3. Precipitation	11
Types of Rainfall	11
Snowfall	13
Hail	13
Sleet	13
Chapter 4. Corrosive Atmosphere	14
Salt Spray	14
Acid Gas	14
Galvanic Corrosion	15
Biological Oxidation	15
General	15
Chapter 5. Sand and Dust	16
Chapter 6. Dynamic Environment	19
Vibration	19
Sine Versus Random Vibration	19
Shock and Drop	20
Dynamic Environment Criteria	21
Chapter 7. Radio Frequency (RF) Radiation Hazard	22
Chapter 8. Philosophy of Specifications	24
Appendix	33
References	36

Figures:

1. Cockpit Temperature Envelope Compared With Outside Temperature During a Test Measurement Series	3
2. Relative Temperature/Humidity Chart	8
3. Psychrometric Chart	9
4. Typical Cloud System/Rainfall Patterns	12
5. Program Sequence	28

INTRODUCTION

It has been experienced by personnel of the Quality Assurance Division at the Naval Weapons Center (NWC), China Lake, California, that one of the major stumbling blocks to resolution of environmental test problems is a lack of common understanding of the parameters. It is the function of this report to present an easily readable summary of the more meaningful aspects of the seven major environments or environmental situations.

The purpose of this portion of the report is emphatically not to present an all-inclusive tome on each environment. The intended audience is the engineer or scientist who has been out of school for sometime and needs a refresher in the overall aspects. It is also intended to give the administrator, who may have never been exposed to this discipline, a quick insight into the various physical relationships affecting the "environment". If, however, an interest is awakened to pursue the given environment in more depth, there are many fine textbooks dealing at length with certain aspects of the given subject.

This part will be used extensively by NWC to provide a common understanding of the particular environment when defining which "test situation" to apply to each type of ordnance. It is intended that it will be used as a "reference" to which any author may refer to provide a common ground for discussion when presenting criteria determination or test result work.

The final chapter is devoted to a discussion of environmental philosophy, past and present. After the realization that a common environmental understanding was necessary, it was recognized that the meaningful communication still was not in all cases achieved and that a general understanding of the philosophy of environmental testing was missing. Therefore, a system of logic is presented to lead the thoughts of others. It is intended that this section be updated as others contribute their thoughts and energies to providing "the" philosophy of environmental testing.

The Appendix contains the results of a literature survey conducted at NWC for the purpose of gathering material presently available on environmental criteria for air-launched ordnance.

Since the subject matter presented in this report is in the primitive stages of natural evolution, the author extends an invitation to all who would join in the advancement of this approach, or respectfully indicate a more usable alternative.

Chapter 1

TEMPERATURE

Temperature is of critical importance because of its effect on the performance and integrity of propellants and electronic circuitry. Military Standards temperature ranges are extremely wide, and any possible narrowing of these extremes, commensurate with good design, will reduce ordnance development costs significantly.

One of the ways that temperature extremes can be reduced without endangering the ordnance is by making a distinction between the meteorological "Standard Air Temperature," and the ordnance temperature.

STANDARD AIR TEMPERATURE

The U. S. Weather Bureau, Department of Commerce, is considered an authoritative source of worldwide standard air temperature extremes, means, and cyclic trends. The National Weather Records Center at Asheville, N. C., is capable of running computer studies on a vast spectrum of meteorological problems. These are of advantage if used only as indicators or precursors of ordnance temperatures. The Standard Weather Bureau temperature readings, unless otherwise qualified, are taken inside a regulation "Stevenson Shelter." This shelter is a white louvered box standing 4 feet above the ground, often over a patch of grassy turf. This box is constructed so that no direct or reflected radiation can strike the temperature measuring element while maintaining free-air circulation through the housing. The shelter has a double air-spaced roof so that reradiation of absorbed energy is minimized. The temperature sensing device is located in the center of the Stevenson Shelter, 5 feet above the ground. (This arbitrary level was chosen because it is eye level for most observers.) The described measurement method has been found to be the best for determining true air temperature without adding serious errors from radiation or conduction.

ORDNANCE TEMPERATURES

The difference between the standard air temperature and ordnance temperature, in a given dump storage situation, is brought about because the ordnance may not be protected from two of the three modes of heat transfer. Also, the density of the ordnance with respect to density of a like volume of air is much greater. A given volume of air can be raised to a given temperature more quickly than the same volume of ordnance. The standard air temperature will fluctuate much more rapidly than will the ordnance temperature. Where air will mix freely, thus transferring

heat rapidly, a piece of solid ordnance exhibits an asymptotic curve of temperature change for a given thermodynamic driving force. An example of this temperature reaction of hardware to atmospheric temperature is shown in Fig. 1.

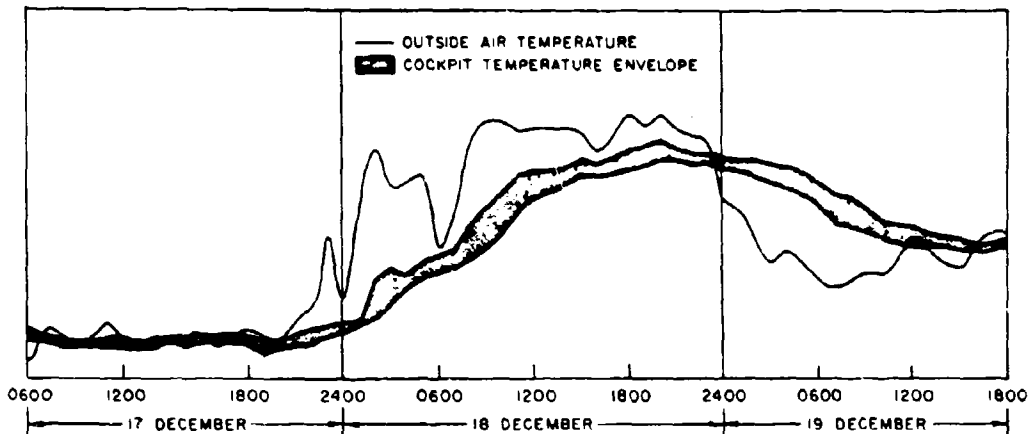


FIG. 1. Cockpit Temperature Envelope Compared With Outside Temperature During a Test Measurement Series.

Because of the rotation of the earth, the heat input to the atmosphere and exposed ordnance is limited in both time and amount of energy. The maximum time of exposure to sunlight is about 14 hours, with varying intensities. The maximum energy applied above the atmosphere is 444 Btu/hr-ft². The transmission through the atmosphere to ground level attenuates 25% or more in most regions of the world. Only in a pure desert atmosphere where water vapor, ozone, carbon dioxide, dust, etc., are nearly absent and the atmosphere is of a density capable of holding the heat can values of 330 Btu/hr-ft² be measured. The National Aeronautics and Space Administration (NASA) and the MIL-STD documents use 360 Btu/hr-ft² as the worldwide maximum. Of the assumed 360 Btu/hr-ft² that reaches the ordnance, some radiant energy is reflected immediately into the atmosphere. The albedo of desert sand is 25%, canvas tarpaulins 5%, and the earth as a whole about 50%. Again assuming maximum conditions of ground absorption, the maximum exposure rate of 360 Btu/hr-ft² is reduced to about 270 Btu/hr-ft². During the exposure of the ordnance, the earth's rotation is such that the angle of the sun's impingement upon the ordnance is constantly changing. The angular path taken by the energy through the atmosphere, hence the equivalent thickness of atmosphere, is also changing. The ordnance is stationary with respect to the earth. Therefore, the energy influx is changing from zero before sunrise to maximum at solar noon and back to zero at sundown. The surface of

exposure of the ordnance has changed with respect to the sun during this cycle such that the surface exposed in the morning is for all purposes sheltered in the afternoon. In the majority of cases the thermal gradient through the ordnance has changed position almost 180 degrees during the exposure cycle. From this it can be seen that the maximum ordnance temperatures are dependent on the mass and the exposure. In practice the exposure time at high temperature is very limited. Under pure desert conditions the temperature zenith is experienced for 1 or, at the most, 2 hours. The temperature of the ordnance when fully exposed can be roughly approximated by a skewed sine wave distribution. If the ordnance is sheltered from the solar noonday insolation, the ordnance temperature will be the same or usually below the noonday standard air temperature. If exposed to solar insolation, the ordnance will exhibit temperatures slightly higher than standard air temperatures. Ordnance skin temperatures may be quite high as compared to the standard air temperature. However, if even a mild breeze is present, the ordnance will not approach the calm day temperature maximum, and in fact will be relatively cool.

During nighttime exposure to the general desert clear sky condition, the ordnance temperature will drop below the standard air temperature because of reradiation from the ordnance to the blackbody night sky. A difference of about 5°F is usually measurable because of this phenomenon.

In the tropics or other nonarid desert regions, the free moisture and contaminants present in the air negate many of the high temperature mechanisms described herein. The finite energy (444 Btu/hr-ft²) is absorbed to a greater extent by these contaminants. Considerable energy is spent in heating the air. When the remaining energy strikes the earth surfaces, the free energy remaining is not enough to produce extremely high ordnance temperatures. The misunderstanding of this has led to the misconception that high ordnance temperatures will occur in the humid tropics. Many WW II GIs can attest to the warmth of the tropics as experienced by a human being. The high relative humidity (RH) and relatively warm air temperatures (100 to 70°F, 60 to 100% RH) are conducive to human discomfort. Ordnance, however, is not subject to the same limitations of respiration and cooling as is a human being. Conversely, on the pure desert, the standard air temperature can be above 100°F and, because of the extremely low humidity, an acclimatized individual will experience no discomfort. Ordnance, however, cannot perspire and will encounter less relief.

LOW TEMPERATURE REGIME

The low temperature regime is far less complex than the high temperature situation. The excursion of low subarctic temperature is generally from 3 to 8 days in duration. When the mean standard air temperature is lowered to a minimum for extended periods of time, the ordnance temperature will tend to follow. Simple thermodynamic conduction theory

dictates that if a thermodynamic driving force exists for a long enough period of time, thermal equilibrium will be attained. Even the relatively high mass density of shipboard ordnance will tend to follow the standard air temperature if the lowered driving force temperature persists for 3 to 8 days. The exposed dump-stored ammunition will react more quickly than that stored in an igloo type magazine. The exact degree of compliance with the above, by stored ammunition, is not empirically known because it has not been measured and reported. The foregoing is derived from work done on cockpit-mounted instruments exposed to the subarctic winter of 1961-62 (Ref. 1). Because of the difference in the mass of a stack of ammunition and the mass of the cockpit shell of an engineless aircraft, there are necessarily varying cooling rates. It is probable that these are significantly different.

The phenomenon of the ordnance temperature being affected by radiation into the theoretical -100°F temperature arctic winter sky was investigated by the author during the winter of 1961-62. It was found that the total variance between clear-sky, low-temperature soak and cloudy-sky, low-temperature soak was only about 5°F . The cloud cover, of course, would obscure the -100°F theoretical thermodynamic driving force of an arctic sky. Contrary to the published theory of equivalent sky-radiation-produced ordnance temperature, the broadband spectrum results were measured to be not on the order of 40°F or more, but only 5°F lower than the standard air temperature. Tentative results of preliminary measurements by Briery of the Natick Laboratories indicate the radiation effect in wintertime to be about 8°F for quartermaster items.

TEMPERATURE DURATIONS

The foregoing paragraphs have discussed in general how the maximum and minimum standard air temperatures cause the temperature of the ordnance to vary. The information given has been necessarily sketchy as to the duration of expected temperatures for any given situation. Table 1 disclosed temperature versus time duration for the major transportation and storage situations. It should be noted, however, that the curves obtained (if these data are plotted) are realistic in the case of high temperatures and subject to $\pm 20\%$ variance in the case of the time durations for the lower temperatures. As stated in the paragraph on minimum temperature regime, the temperature-time duration interaction has not been measured and reported; therefore, the criterion for this determination must be interpolated from the best available data even though these data are not strictly applicable to this determination. It is obvious that work must be done so that the unacceptable ignorance factor of $\pm 20\%$ can be reduced to a more workable value. Focusing of effort in this direction will tend to halt overdesign costs and lessen ordnance deployment limitations.

TABLE 1. Tentative Temperature Duration Indexes (Extreme).

Time, hr	Temperature, °F				
	Hours at or above the indicated high temperatures				
	Transportation		Storage		
	Ship, °F	Boxcar, °F	Igloo, °F	Dump (exposed), °F	Dump (in container), °F
1	90	119	100	140	130
2	90	117	95	135	125
4	90	115	95	120	120
8	80	110	90	100	115
12	75	105	90	90	100
2	..	...	...	-40	-40
4	..	-30	...	...	...
12	..	...	...	-30	-30
72	..	-20	...	-20	-20

The information in Table 1 is extremely pessimistic, or conservative, for air-launched tactical propulsion systems. It is not likely that the parts of a sophisticated guided missile will be subjected to dump storage, if even primitive shelters exist at the location. Any type of cover will greatly moderate the extreme temperatures of exposure. It has been shown statistically in the NWC series of publications, "Storage Temperature of Explosive Hazard Magazines," (Ref. 2) that any shelter will reduce the maximum exposure temperatures and raise the minimum exposure temperature.

Chapter 2

RELATIVE HUMIDITY

This parameter is possibly the most misused of the regular qualification tests. The relative humidity (RH) in any situation must be referred to a temperature (Fig. 2). There are only finite levels that humidity can achieve during extremes in temperature. In some cases, the percent of humidity present is meaningless even though the numerical value is high (Ref. 3).

If, for instance, the atmospheric condition was 95°F with an RH of 95%, that would mean that there is approximately 0.035 pound of water per pound of dry air (Fig. 3). If, by some phenomenon, the temperature is raised, the RH can only drop because the absolute moisture content of the air remains constant in a closed building. In this case, given a storage shed temperature of 160°F and 0.035 pound of water per pound of dry air, the RH is now less than 20%. From this it can be seen that the MIL-STD common value of 160°F, 95% RH is beyond the realm of natural possibility.

At low temperatures the RH will be high, even 100%, in almost all natural circumstances. At 40°F an RH of 100% is equal to about 0.005 pound of water per pound of dry air. (This is equal to about 15% RH at 95°F.) The two main parameters governing RH are the amount of free water available and the capacity of the air to hold water.

High RH in conjunction with elevated temperatures is a cause of extreme discomfort in human beings. The normal body temperature of 98.6°F is regulated by the sweat glands. When the atmospheric temperature is higher than the body normal, perspiration takes place in an attempt to remove the excess heat through a liquid evaporation process. However, when the high temperature is coupled with high moisture content, the perspiration will not readily evaporate and the human is uncomfortable. When the air is relatively dry, such as in a desert environment, evaporation is rapid and high temperatures are much less bothersome.

The reaction is entirely different in the case of ordnance or other nonliving items. High humidity does not cause an increase in the "discomfort index." A temperature of 100°F in a piece of ordnance is reached by the same number of heat units whether the RH is 10 or 100%. It is therefore imperative that ordnance being evaluated be instrumented for both temperature and humidity. Reliance on the "feel" of even the best trained technician is not trustworthy since extreme heat and human discomfort is in reality an organic and mental condition and does not reflect a similar reaction by the hardware.

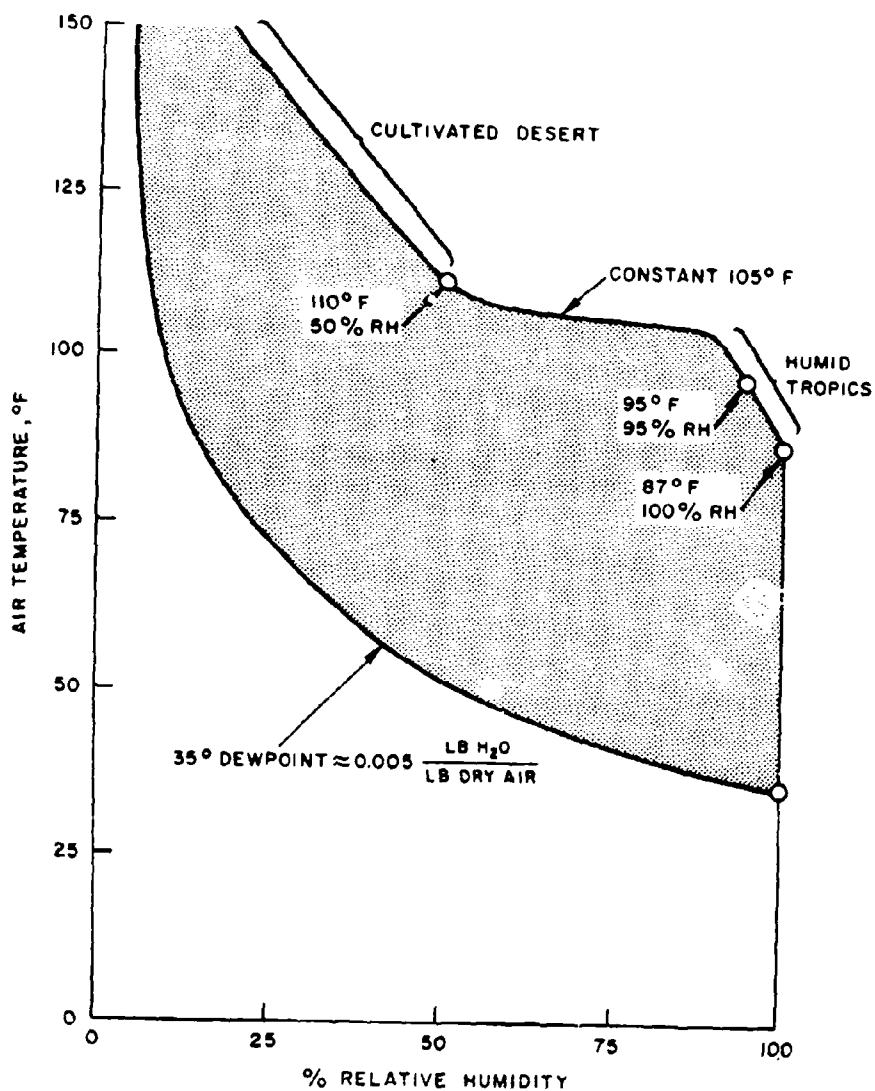


FIG. 2. Relative Temperature/Humidity Chart.

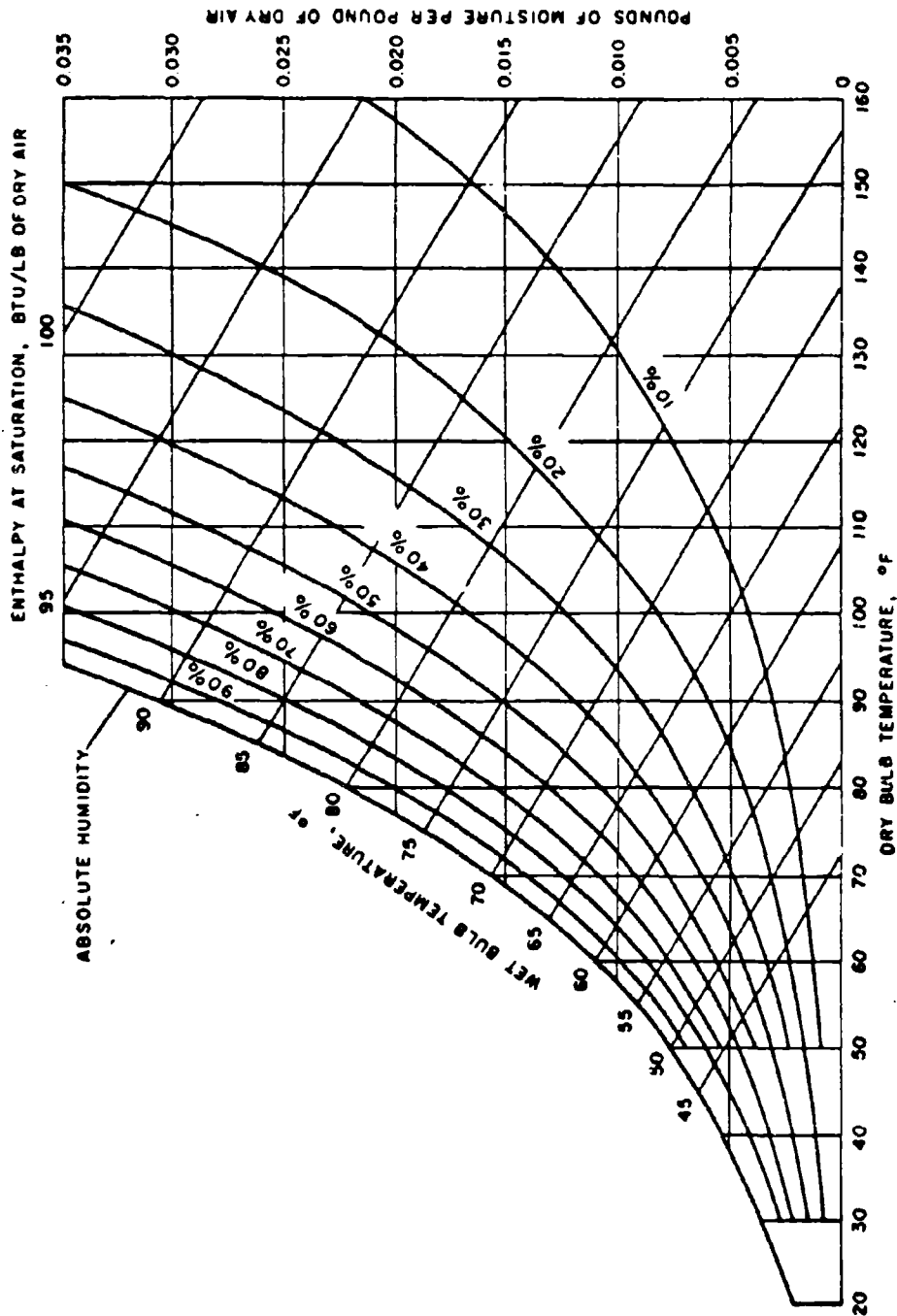


FIG. 3. Psychrometric Chart.

Figure 2 is a graphic compilation of the humidity factors reflected in this document. The upper boundary consists of the 100% RH line from a 35°F dew point through 87°F. The 100% RH at 87°F is defined as the temperature and RH if a 95°F at 95% RH situation is assumed as the top design parameter.

Since the normal observed high temperature excursion, in the areas of the world where the 95°F/95% RH situation occurs, seldom reaches above 105°F, this value is established as the upper temperature "extreme" for this type of exposure.

The 105°F temperature also is arbitrarily used as the upper envelope to join the "humid tropics" (95°F/95% RH) with the "cultivated desert" exposure (110°F/50% RH). The curve is smoothed to the constant temperature line of 105°F with RH dropping from 90 to 55%. The curve is then influenced by the 110°F at 50% RH value which is assumed to be the worst desert exposure possible. (This occasionally occurs at the Naval Parachute Facility at El Centro, California. The situation is unique because this facility is in the heart of a cultivated, irrigated desert valley.) This point is joined to the 135°F at 30% RH point for dump storage by a constant moisture line. The natural forces would have to be finely attuned to match this conservative envelope.

The lower boundary consists of the 35°F dew point line. This constant moisture line is extended throughout the RH excursion. The area between these boundaries can be treated as fair design criteria. Any temperature excursion below 35°F can be treated as if the RH is at 100%. The difference between 0 and 100% RH below 35°F is 0.004 pound of water per pound of air which is negligible.

Chapter 3

PRECIPITATION

Rain, snow, hail, and sleet are different forms of moisture from the upper air (Ref. 4). The differences in character are due to the conditions under which precipitation is formed from water vapor condensed by cooling. Clouds are formed when the moist air is lifted upward and cools below the dewpoint. Droplets form on the condensation nuclei and are usually very small — about 0.001 inch in diameter. These droplets are supported by the air and drift along instead of falling to the ground. In order for cloud droplets to fall as precipitation they must grow enormously. Two processes are believed to contribute to this growth. The initial process occurs as the temperature at the top of the cloud drops below freezing where it is usually noticed that the droplets do not readily freeze, but become "supercooled". As the cloud reaches higher altitudes, however, some ice particles form and these grow at the expense of the supercooled droplets, the moisture leaving the droplet surfaces and condensing on the ice particles. Following this initial growth, the ice crystals begin to fall and their further growth results from collision and coalescence with other drops and ice crystals. If temperatures are below freezing all the way to the ground, the elements fall as snowflakes. If it is warm in the lower levels, the snowflakes melt and form raindrops.

TYPES OF RAINFALL

Continuous rainfall in amounts of 2 inches per hour or more for any portion of a day is considered a deluge of flood proportions. Rainfall has been found to fall into three general classifications (Fig. 4).

1. The first is a gentle continuous rainfall and is characterized by a ground-cover to sky-cover ratio (between overcast sky and wet earth) of one to one. This type of precipitation can last for days.
2. The second classification is a variable rainfall in that it will exhibit gentle showers followed by spasmodic fall rates up to 1 inch per hour for periods of from 5 to 15 minutes duration. This type of storm generally moves in a thin broadside pattern. The sky-cover area of the storm will be the same as the first example, but the ground-cover area is only about one-quarter to one-eighth that of the sky-cover area. This type of precipitation cannot last as long as in classification 1 because the water reserves are depleted more rapidly.
3. The third and least encountered type of rainfall is the cloud-burst. The desert areas and tropical zones are the normal recipients of this form of precipitation. The sky-cover is the same as the previous two examples; however, the ground-cover is only a small fraction of that

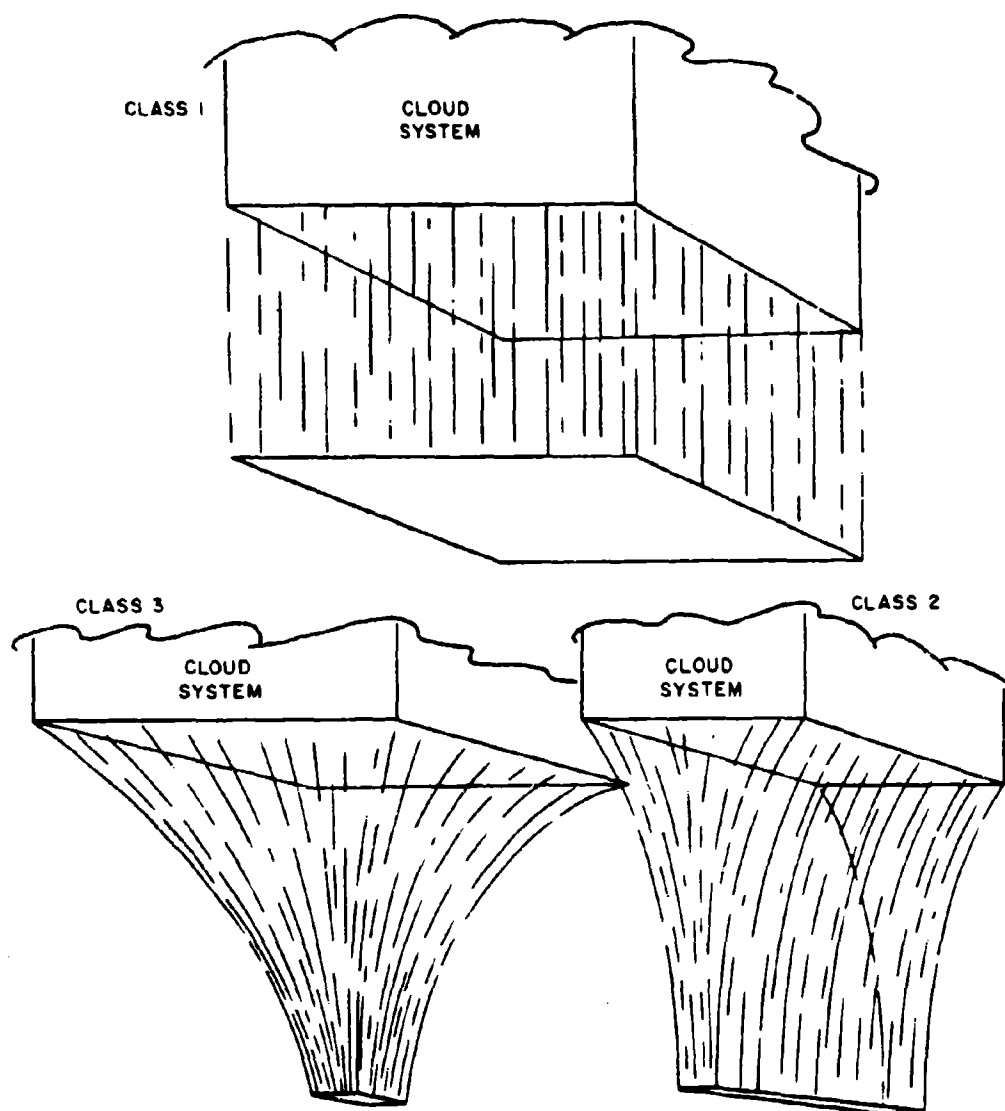


FIG. 4. Typical Cloud System/Rainfall Patterns.

in classification 2. Wind conditions are generally such that the available water in the storm front is focused into an acute, tapered "funnel". The path of such storms is extremely narrow, on the order of 600 yards. (The record measured rainfall in this class occurred in 1947 at Holt, Missouri, and measured 12 inches in 42 minutes.)

SNOWFALL

Snowflakes accumulate on the ground to considerable depth but the water content of unpacked snow is rather low. Under ordinary conditions it takes from 8 to 12 inches of snow to equal 1 inch of water. The ratio of 12 inches of snow to 1 inch of water is normal. In limited areas; i.e., Mammoth Mountain region of California, the more dense snowfall has a ratio of 10 inches to 1 inch of water. The ratio of 8 inches of snow to 1 inch of water is an extremely rare occurrence.

HAIL

True hail occurs only in warm weather and usually during thunderstorms when strong vertical air currents are present. It is reasoned that hailstone formation is started when a raindrop is carried up to where the expanding surrounding air is cooled below the freezing point. The raindrop is frozen, and then, falling back into a warmer layer of cloud and rain immediately collects a coating of water, only to be carried by another gust of rising air back into the higher layers and refrozen. This process is continued by separate gusts of rising air until the hailstone becomes so large that it falls to the earth.

A hailstone is similar to a classification 3 rainstorm in that it is a localized occurrence, usually of short duration (30 minutes). The hailstones are generally about 1/8 inch in diameter but have been known to reach the size of a golf ball. The size of the hailstone is governed by the vertical turbulence of the storm.

SLEET

During the winter season, rain sometimes falls through a layer of air where the temperature is slightly above freezing and afterward falls through colder air and reaches the earth as frozen raindrops or ice pellets. This form of precipitation is sleet (Ref. 5).

After a prolonged or severe cold spell it sometimes rains before the temperature of the ground and the lower air has risen above the freezing point. The rain then freezes to everything it touches and forms a coating of ice.

Chapter 4

CORROSIVE ATMOSPHERE

The grouping of criteria in this Chapter includes mechanisms that can lead to the attrition of the ordnance physical structure or designed ability. Salt spray and fungus are the usual criteria that have been advanced to cover this situation. The tests set forth in present documentation are not the proper solution to the problem of corrosion of in-Fleet ordnance. Thus, the true mechanisms of the corrosive driving force, as it pertains to Naval ordnance, have not been fully researched or documented.

When the corrosive atmosphere is taken as a group, definitive statements can be made about the severity of the entire problem. Precise knowledge about the separate mechanisms of corrosion is meager. The Naval Ammunition Depot (NAD) at Oahu, Hawaii, reports that ordnance stored at the Naval Magazine, Guam, is rendered unserviceable by corrosion at a more accelerated rate than similar ordnance stored at NAD, Hawthorne, Nevada. It can, therefore, be said that corrosion in the Pacific Ocean island areas is severe. The problem limits still have to be measured empirically but it is known where the problem exists. It is also known that corrosion is a time-dependent function. Observation indicates that during any normal transportation of ordnance, corrosion is negligible because the time of transit is relatively short. In general, the following is a brief summary of the recognized individual criterion herein grouped as a corrosive atmosphere.

SALT SPRAY

At present, Federal Test Standard No. 151, Test Method 811, is used to simulate the effect of salt spray. This calls for reagent grade sodium chloride in distilled water, with a pH-value of 6.8 to 7.2. An examination of the water of any ocean of the world will reveal that this laboratory salt solution doesn't approach the composition of seawater. Where this solution has been used for ordnance testing, it has been shown that the results at the conclusion of the test bore no similarity to the demonstrated results observed on Fleet-returned pieces of the same type ordnance. Naval ordnance has in some cases passed the Federal Standard salt spray test satisfactorily only to fail because of corrosion in Fleet service. Work should be done immediately to determine a usable criterion for salt spray.

ACID GAS

The majority of Naval ships are powered by fossil fuels. These fuels are divided into two categories, Bunker C and Navy special fuel oil. By-products of fuel oil combustion are composed of many compounds. The insidious mechanism here is the formation of ash, water, soot, and an average concentration of 900 parts per million of sulphur dioxide gas.

Sulphur dioxide is easily converted to sulphurous acid in the presence of water. This mechanism in itself can cause colloidal droplets of acid to be spread throughout the shipboard area. The ash and soot serve as activated charcoal, absorbing the sulphurous acid and other acid gases in solution. When the system is "blown down", these highly acid soot flakes permeate the entire shipboard area and the ordnance stored therein. Between the normal airborne salt ions and the products of combustion of hydrocarbons there could be sulphurous, sulphuric, hydrochloric, nitric, and carbonic acids. Combinations of these are known for their corrosive powers.

GALVANIC CORROSION

Galvanic corrosion can be instigated by the widespread use of protective metallic coatings and close proximity of dissimilar metals. The normal service use that many ordnance items receive is sufficient to chip plating or scratch protective coating away from the parent metal. The many electrolytic acids present can then cause corrosive action.

BIOLOGICAL OXIDATION

The present fungus and bacteria specifications call out six species of fungi. Investigation by Dr. Bruce Lee of the Detroit Arsenal revealed that none of these cause the damage so prevalent in the tropics. These six species of fungi were easily obtained laboratory specimens during the late 1940's, so were used when nothing better was known or available. Dr. Lee identified various strains during his work in Panama, though more work needs to be done and reported to establish their interrelation in respect to equipment deterioration.

GENERAL

Corrosion can be generally described in terms of classical chemical reaction kinetics; however, the majority of the research work in this field has been devoted to the solution of specific situations that caused failure. While these pinpoint investigations are valuable, of far greater importance would be an overall concept descriptive of the corrosive potential in a given situation of the weapon's service life. Once the overall matrix has been developed, the overall solutions obtained to date can be categorized into the overall picture of corrosion. When the generalized situation is understood, then the specific solutions can be incorporated in their proper perspective and will become of universal value. Presently, the specific solutions cannot be placed in proper context since the context does not exist.

In summary, it can be seen that any numerical values for "corrosive atmosphere" would be at best accurate to only an order of magnitude. This area of the total environment is in dire need of exploration and classification.

Chapter 5

SAND AND DUST

Sand and dust criteria have been misrepresented for decades. As inhabitants of a sandy, arid region, personnel stationed at NWC experience a radically different set of "sand and dust" circumstances than those documented in present sand-and-dust specifications.

For example, at NWC, windblown low-level sandstorms occur that are capable of seriously damaging glass and painted surfaces on stationary vehicles, equipment, and structures within a matter of 3 hours; i.e., 24 December 1964. Such occurrences are not limited to NWC so it must be considered universal in all desert or semidesert locations, although the exact criterion is unreported.

The established sand and dust criterion as presently used in MIL-STD specifications was originally derived from results of early work done by the then Army Air Force (pre-1949). The philosophy by which this criterion was measured was basic; i.e., "what level of exposure will an electronic equipment black box, mounted inside an aircraft, experience when that aircraft is parked on a desert airfield." The dust and sand particles captured in such units are very fine. Because a criterion had to be rapidly established for analogue testing, foundry sand (140-mesh silica flour), which was mined near Akron, Ohio, was readily available to Wright Field. From lack of choice, the other services and industry used this criterion, though in recent years the 500 feet per minute wind velocity has been raised. It can be readily seen that Naval ordnance will not be exposed to a sandstorm in the same manner as an electronic equipment black box that is mounted in an Air Force aircraft. Therefore, the mechanism of sand and dust travel, concentrations, and particle size distribution still have to be investigated to bring the "analogue" test into line with reality.

The phenomenon of "desert pavement" with respect to the severity of a sandstorm must also be integrated into any future study of this environment. The action of wind, rain, and vegetation combine to form a layer of dense sand or soil on the surface of a desert. This nature-formed "desert pavement" has a strong tendency toward holding the sand surface firm during a windstorm. This phenomenon can be observed in any desert valley where an attempt has been made to reclaim the land. The area disturbed by grading or cultivation will produce clouds of dust much larger and more intense than will the surrounding virgin desert in a given wind condition. It must, therefore, be given serious consideration that whenever a new activity, with the attendant disruption of the earth surface, is developed in a desert area that there will be greater sand and dust hazard than the virgin territory might have previously displayed.

Desert Pavement

In the semi-arid regions of the world, the soil seems to exhibit a greater tendency to stick together more at the surface layer than in the subsurface layers. This agglomeration of the top layer will be referred to as the desert pavement. This pavement is in evidence extensively in all desert or "dry" areas worldwide. It has been observed to exist not only at NWC in the Mojave Desert but also in the Philippine Islands and throughout Southeast Asia during the dry season.

The desert pavement in general consists of a surface layer 1/4 to 2 inches thick. The mechanical strength of this layer varies with the consistency of the soil but in general it is not able to withstand the passing of a modern military force.

For clarification, the analogy of a frozen lake can be used. The layer of ice on the surface is the equivalent of the desert pavement. The ice usually cannot support too much weight before it is destroyed. The ice suppresses waves and holds down the spray, which is equivalent to the main constituent of a "sandstorm".

The profuseness of a sandstorm for a given wind velocity varies drastically with the amount of disturbance to which the desert pavement had been subjected. As long as the desert pavement remains intact, the wind must exhibit extremely high relative velocities to raise a dust haze. If the desert pavement has been totally destroyed, a zephyr will be sufficient to cause the formation of a dust haze. A full-blown desert wind will blot out visibility and make it very uncomfortable for man and ordnance. This phenomenon can be observed at any new housing subdivision throughout the southwestern United States.

From the time of the first ground breaking, through the time when lawns or concrete take the place of the desert pavement, the dirt will permeate into everything when the wind is blowing. The anomalous thing about the example is that during the wind-carried dust storms, the indigenous desert is crystal clear. The contrast is striking when it is observed from one of the foothills usually surrounding the desert valleys.

Military Application

The desert pavement phenomenon is merely of passing interest until it is applied to ordnance and the military in general.

When an area is chosen as a logistic supply point, the first thing that must be done is to move in men and material with vehicles, such as the workhorse 6 X 6 trucks. These vehicles proceed to shuttle supplies and equipment into the area at a tremendous rate. With the tent city and stacks of munitions in place, the logistic supply point soon takes shape. If one observes the tracks that serve as roads, he would notice

that instead of a granular surface with spasmodic vegetation interspersed throughout, the roadway consists of a fine, sometimes fluidized, dry powder. In some locations, the dry powder will react as if it were a fluidized bed, in that it exhibits a reaction resembling a splash when it is stepped into. When a vehicle is driven through the dry powder, even at 15 miles per hour, a dust cloud is forced into the atmosphere to a height of about 20 feet.

No longer can we depend on the physical relationships of the non-disturbed, virgin desert. The constant movement over the "roads", through the living area, and in the storage area, soon divest the general area of vegetation and the desert pavement.

Chapter 6

DYNAMIC ENVIRONMENT

For the purposes of this document, the dynamic environment consists of vibration and shock in the standard sense of the meaning, and mis-handling of ordnance.

VIBRATION

The vibration criterion as presented herein includes the complete vibration spectrum from 5 to 3,000 Hz, both sinusoidal and random excitation. The tables in NWC TP 4464, Sections 1 and 2, do not make mention of the random type of excitation only because the references used to establish the vibration criterion, under any given environmental condition, report sinusoidal components only. In actuality, it is questionable whether or not the sine wave components are those giving the greatest amount of trouble. For example, an aircraft exhibits a vibration spectrum that shows the sine wave excitation associated with the major frequency of the power plant. The overall spectrum also shows a moderately high level of random vibration throughout the frequency band from the lowest measured levels, usually 5 to 20 Hz, through the 2,000 Hz level. From 2,000 through 3,000 Hz, some random energy is present, although the magnitude seems relatively unimportant.

Because of the limitations of vibration-producing test equipment, all vibration-producing criterion research was reduced with an intent toward use in sinusoidal analog equipment (Ref. 6). The first deviations from this practice were evident in the early 1960's. The traditional Military Standards still recognize only sine wave vibration. MIL-STD-810, however, does recognize and specify random vibration procedures, although the tests are generally designed on what the state-of-the-art of random vibration simulation machines can do, and not what the actual situation is.

SINE VERSUS RANDOM VIBRATION

The following is not intended to be definitive but rather to give a glimpse into the usefulness of each type of vibration. The following example cited did happen and the solution was obtained because a thorough understanding of both sine and random vibration existed in the mind of the designer.

During the development of a high reliability triode-type vacuum tube, the designer placed the development unit in the hands of the Engineering Development Laboratories for vibration testing. The laboratory properly

subjected the triode to the specified sinusoidal vibration of 20 to 2,000 Hz. Both a slow sweeping procedure and a resonance dwell procedure were used. It was found that the grid, plate, cathode, and heaters all had their major resonances in this vibration spectrum. However, at the proposed development energy level, the separate elements had sufficient room to move at a single frequency during resonance without touching the adjacent component. The vacuum tube was released as being satisfactory and highly reliable. The failure reports from Fleet service indicated that this tube was shorting between plate and control grid, or control grid and cathode in actual Fleet use. The fault was found when the vacuum tube was again subjected to a series of vibration tests. When a band of random frequencies was fed into the vibration equipment, all four units of the tube were excited at once, each at its own resonant frequency. With all four units moving at once, there was not enough space in the tube to maintain electronic separation. The random excitation had more closely duplicated the service environment of this tube than had the sine wave excitation.

In general, sine wave excitation is a useful developmental tool to determine where the major resonant frequencies of a unit exist. When the known troublesome resonances have been eliminated, then the random excitation demonstrates whether or not the unit is stable in the actual usage situation.

Both types of vibration have their distinct usages and advantages, although random vibration is not generally used enough in the development program.

SHOCK AND DROP

Shock and drop are handled separately in this part because in the final analysis not enough data exist for complete correlation. Shock is herein defined as a single blow received in a dynamic situation such as movement on a truck or other vehicle, or a blow received while the ordnance is being transferred from one ship to another. Drop is herein defined as the shock experienced from accidentally dropping the ordnance. The impact surface is also specified so that "drop" and "shock" can be correlated in the future.

The shock criterion specified for most situations is somewhat incomplete. The complete definition of the shock parameter requires shock force, time duration of the force, and the force pulse shape. Almost all of the shock data published are lacking one or more of the essential elements.

The "drop, no damage" criterion established herein has been the direct result of observations by the author during fact-finding visits to various NAD, Fleet ship, and other Naval ordnance facilities.

Observations indicated that, during the loading and handling of the palletized ordnance on trucks, railroad cars, aircraft, or ships, the equipment used is mainly limited to forklifts and cranes. Navy rules and regulations have established that ordnance crews must be comprised of at least two members; therefore, it is highly unlikely that any excessive ordnance drop of more than 1 foot would go unnoticed or unreported. Even inexperienced or careless forklift operators are not apt to drop a pallet of ordnance more than 6 to 8 inches while sliding the load off the forks onto the vehicle bed or ordnance stack.

Crane operators are subject to greater misjudgment in handling ordnance packages. Lack of clear, direct vision plus reliance on secondary direction commands can lead to drops of 2 to 5 feet at the bottom of the hold during stowage.

DYNAMIC ENVIRONMENT CRITERIA

Any attempt to establish the environmental criteria with respect to vibration for an oncoming weapon system based on past measurements can be at best only partially successful. The mechanics of dynamics are so complicated when referred to a guided missile that even if the myriad of vibration inputs, or forcing functions, were known for one system, the response of a second system will be different and in some cases almost completely so. This being the case, if there is any doubt that failure due to vibration is a probability, then actual flight measurements should be made on prototype hardware to define what the response of the unit and its components will be. Any structure can, and does, in some cases amplify or dampen the original driving force. Therefore, a nominal input of 5 g can be amplified by some component's response to as much as 100 g. Conversely, a 20 g input can be damped out to virtually nothing by another component in the same piece of ordnance.

Considerations such as these dictate that for any development program, the services of a competent "vibration man" are highly desirable, and in some cases mandatory to the completion of the project.

Chapter 7

RADIO FREQUENCY (RF) RADIATION HAZARD

Malfunction of ordnance containing electronic circuitry is a definite possibility under certain conditions of RF radiation exposure. A very informative paper discussing the theories of this RF hazard has been prepared but has not as yet been published. The following paragraphs are quoted from "RF Radiation Hazard - Electromagnetic Field Strength, an Environment Parameter", by Russell N. Skeeters, Code 5525, NWC, March 1965 (Unpublished).

"Electromagnetic energy is propagated into space intentionally from radio and radar transmitters and incidentally as a by-product of electrical power transmission and of the use of electrical equipment in which electrical transients, corona, arcing and sparking generate electromagnetic radiation. These effects are measured in units of electromagnetic field strength -- volts per meter for the electric field and amperes per meter for the magnetic field -- or alternatively, as power density in watts per square meter or milliwatts per square centimeter. The instruments for taking field strength measurements are essentially calibrated receiving sets specially designed for particular requirements such as amplitude and frequency range and polarization of electric and magnetic fields. The particular requirements determine the type of field probe or antenna and the design of the measuring instrument proper as a high-frequency voltmeter or ammeter.

"The existence of an electromagnetic environment in military situations creates compatibility problems. These may be considered under two categories -- electromagnetic compatibility and electroexplosive compatibility. Although the two fields have a common area, they demand separate treatment. Their main difference is in the magnitude of field strengths that must be considered. With electromagnetic compatibility, the concern is with being able to use electromagnetic equipment, often of extreme sensitivity (as for receiving data transmitted from a satellite) in a noise environment of millivolts or at most a few volts per meter. With electroexplosive compatibility, the problem is being able to handle, and use with safety, electroexplosive ordnance in electromagnetic environments that may reach hundreds of volts per meter as on an aircraft carrier where ordnance must be handled in close proximity to high power transmitting antennas. In dealing with electroexplosive compatibility, the relative insensitivity of electroexplosive devices as compared to electromagnetic devices is helpfully important. For example, a current of one-tenth of an ampere may be tolerated in certain electroexplosive devices but a noise current of a microampere or less may render a sensitive receiver inoperative.

"The principal factors that determine the electromagnetic environment are the power level of the source and the distance from the source. Some typical examples will illustrate how these factors operate. First, consider the near field area surrounding a radio transmitting antenna. A pole antenna radiating 10 kilowatts can generate a field as great as 300 volts per meter at 10 feet from the base of the antenna. Second, consider a 50 kilowatt broadcasting antenna. At 1 mile the field strength may be around 2 volts per meter but at greater distances the field strength falls off rapidly due to ground absorption so that at 10 miles it will be less than 1% of this figure. The practical significance of the distance factor for ordnance safety is that concern be generated only with the near field region of a transmitting antenna. Ordnance ignition circuits (assuming reasonably good design) will not be adversely affected by transmitting antennas at least one-tenth mile distant. For near distances it may be necessary to take measures to suppress radio frequency pickup in ordnance circuits to protect against high power electromagnetic generators."

Chapter 8

PHILOSOPHY OF SPECIFICATIONS

Military standard specifications have grown out of the necessity for environmental testing as shown in World War II. It was seen during that period that hardware designed for use in the Continental United States might not be sufficiently versatile for use on the African deserts or during the Russian winter.

Because of the urgency for establishing a general environmental test plan quickly, and the obvious lack of basic data on the environments to which the hardware was being subjected, a set of nonanalogous tests were formulated. Indications are that a vast amount of work was attempted to more finely determine the physical relationships and natural laws that govern criterion maximums and minimums. With the conclusion of World War II and the rapid demobilization of our Armed Forces, the confusion and reorganizations of military field laboratories caused the vast majority of the results of this work to be misplaced or buried in myriads of extraneous data. The progress on general Military Standard environmental test procedures advanced at a slow pace until the early 1950's when MIL-E-5272, MIL-E-5400, and MIL-T-5422 (BuAir) emerged. These became the parent testing documents from which the major proportion of our present systems of test specifications were derived. It is the apparent philosophy of these specifications that will be explored here as the example of the aim of existing specifications (Ref. 6).

An examination of most existing Military Standards shows, for example, operating temperature extremes of +165 and -65°F. These temperatures are generally combined with time durations of 8 to 16 hours each, and usually the item of hardware is subjected to a cycling between these two temperature extremes. The philosophy of the test is that this treatment is more severe than the treatment the hardware will experience in service; therefore, if the hardware will pass this test, it will survive irrespectively in Fleet use. This line of reasoning mistakenly assumes that the physical relationship between temperature and time on which the JAN-STD cycle is based is valid common knowledge and that the cumulative effects of the life span of in-Fleet ordnance can simply be compressed into 2 to 4 weeks of cyclic "overtest". It is also erroneously assumed that the state-of-the-art of all materials used is such that we can design to this arbitrary limit at will. The assumption also implies that each criterion is separate and distinct from all others, and that, if the hardware is successfully exposed to all recognized criterion separately, it will therefore be immune to combined criterial effects. In one criterion, for example, sinusoidal and random vibration, the recognition of the fact that the test was at best arbitrary led to the designing of a test procedure suited to the capabilities of archaic testing equipment and not aimed directly at experiences the hardware would be expected to

survive in Fleet service. The above "causes" have led to the "effect" that vendors have spent many productive hours devising ways for their equipment to pass the arbitrary military standard environmental test, only to have the hardware fail in Fleet use.

It must be honestly and emphatically stated that during the late World War II era this philosophy was acceptable. The fluid situation precluded establishment of any sound method of predicting the successful implementation of military hardware prior to weapon commitment. This philosophy provided the primary impetus for the first step in the necessary program to attain fully workable, economic test procedures for the development of Fleet hardware. But like any preliminary excursion, it should be followed by later refinements.

The state-of-the-art of weapons development and environmental science is such that the expenditure of funds and manpower necessary to meet an arbitrary test that may or may not point out areas of potential failure is no longer justified on the basis of demonstrable results. The average weapons system of today is far more complex than that of systems circa 1944. For instance the Sidewinder and Sparrow missile systems can be compared to the 50-caliber aircraft armament on World War II vintage F6F fighter aircraft. Also, the backlog of formal and informal data on the environments to which these new weapon systems will be exposed, and the better interpretations possible of these data with respect to a particular weapon system, negates the arbitrary method of "Go-No Go" testing. In many cases, extensive modification programs have been necessary after introduction of a new weapon system to the Fleet. It is a firm consideration that such "crash" programs are generally more expensive and certainly more troublesome than a proper program of predevelopment assessment of actual Fleet conditions to which the specific weapon system would be exposed. Crash "fix" programs usually yield little or no data by which the same circumstance can be avoided in a following weapons system.

The usual defense for the use of the present test system is that it has been used with some success for the last 20 years, that a backlog of by-product information has been built up on specific items, and that an acceptable Fleet service record for hardware so tested has been compiled. The backlog of information, in reality, may be that by over-designing part or function "A", part or function "B" has enough load or function relieved so that it works satisfactorily in Fleet usage, although in fact the independent function of part "B" is never truly tested. If this is the case, more time and money is being spent to "beef up" part or function "A" than is required for mission completion. As a consequence not much is known about the true strength of "B" versus "A".

Should the weapon component be required for another perhaps unrelated mission in a different weapon system; i.e., Sidewinder and CHAPARRAL, the dependability of either component as an entity is not

firmly established. Usually the proponent of this logic cannot reveal whether or not the tests used are factually pertinent precursors of trouble, whether units are being test-failed that would otherwise perform satisfactorily under the less strenuous demands of Fleet service, or how much expensive effort is being needlessly spent to satisfy the admittedly arbitrary test requirements. Expediency dictates that only the failures are examined while successful performances and the contributing factors are glossed over or ignored. The degree of over-design is never clearly defined.

Under the present philosophy of arbitrary "Go-No Go" testing, the true status of each environmental criterion is not known with respect to a given piece of hardware. For instance, it is assumed that the salt spray test is a good measure of whether a piece will resist in-Fleet corrosion. Thousands of dollars are spent to subject hardware to this test. Yet hardware that has passed this laboratory test with flying colors is returned from Fleet use as unserviceable because of corrosion. A crash program is then instituted to fix that specific item; however, no thought is usually given to defining the general problem, studying it, and providing a more representative series of tests to indicate whether or not a weapon will be rendered useless because of corrosion in Fleet service. The same comment can be expressed about the majority of the environmental criteria.

There are two generally accepted alternatives to the foregoing philosophy. The first approach, ideally pursued, consists of: development of the weapons system; physical nonsimulated exposure of individual weapons to (1) arctic winter, (2) desert summer heat, (3) tropical heat and humidity; and subsequent firing of the separately exposed weapons. Successful performance in the three environmental areas is a positive indication of good design. Failure to fire necessitates instigation of a "fix" program to correct the design imperfections. This method is basically "after the fact"; however, it can be good if sufficient data, both meteorological and ordnance instrumentation are taken, correctly reduced, and adequately documented so that it can be correlated with like data previously collected on similar projects. However, the hard fact is that the practice has been to unceremoniously expose the uninstrumented weapon to extreme conditions for a "more or less" period, then fire it. As before, success is accepted and failure is expensively researched and hopefully corrected. In this latter case, the environmental data taken are generally limited to meteorological data only.

The foregoing method fails the overall objective because insufficient data are gathered to be of any concrete assistance in the establishing of a test result information source. Testing conducted in this manner lends very little towards an understanding of the environments and a consequent updating of the state-of-the-art. An additional point of conjecture is raised in this method of testing when a mild rather than normal season is encountered. Doubt will remain regarding the validity of the test in terms of the environmental severity expected by the Armed Forces.

All weapons systems will not be necessarily exposed to worldwide environmental situations during their projected Fleet service lifetimes. The operational theaters can be a predesign decision in most instances. For an admittedly extreme instance, it would be completely unnecessary to require arctic performance capabilities in a weapon system primarily intended for use in temperate zone marine hostilities. The points of variance in this case are far apart to stress the point; however, the parametric variables can be closely pinpointed with each narrowing of limitations resulting in less strenuous design requirements and reduced project expense. It cannot be stressed too strongly that a weapon system should be "designed to" its own unique usage environment whether this be worldwide or much narrower in scope.

The second alternative is to divide the service life of a weapons system into its generalized phases. For example, all weapons have a projected life span from time of manufacture through impact on a target. This life span generally is divided into three distinct phases: raw materials to assembly of weapon, assembly through to seconds before launch or firing of weapon, and the launch or firing to target phase. Figure 5 shows the generalized sequence of events from program start through delivery of completed hardware into Fleet service. The criteria determination should be generally nonhardware oriented. The physical situations to which the desired weapons system will be exposed are recognized, not whether the weapons system is made of material "X" or "Y" or how that material will react to the physical situation. The method is to mentally picture an atmospheric cube placed in all the normally projected situations that the weapon system will experience. The cube of air can be expected to experience any set of environmental criterion that the weapon system will experience in that situation. However, actual hardware will be necessary for use in determining, as closely as possible, criterion such as the ordnance temperature, or shock and vibration levels. In the majority of cases, there are weapons in existence that are nearly analogous to the proposed weapons system. These can be used for obtaining the required measurements. Most natural environments and the induced environment of "Drop, No Damage" can be assigned a value with little or no idea of weapon shape. If the system is to be stored in the open, it can be reasonably assumed that precipitation will be experienced. The amount of rain per hour can be determined from separate information sources. The three-part criteria determination should more properly be considered as two part, deleting the raw material-to-assembly phase. The raw material-to-assembly portion is strictly a quality control function and is definitely material oriented. This step is usually under the supervision of Navy or Government inspectors. The vendor is required to conform with procurement specifications to ensure acceptability of the finished module for purchase by the cognizant Navy inspector. Therefore, unless there are quality control problems with a given material, i.e., an igniter mix, etc., this step should be a joint responsibility of the vendor and the Navy.

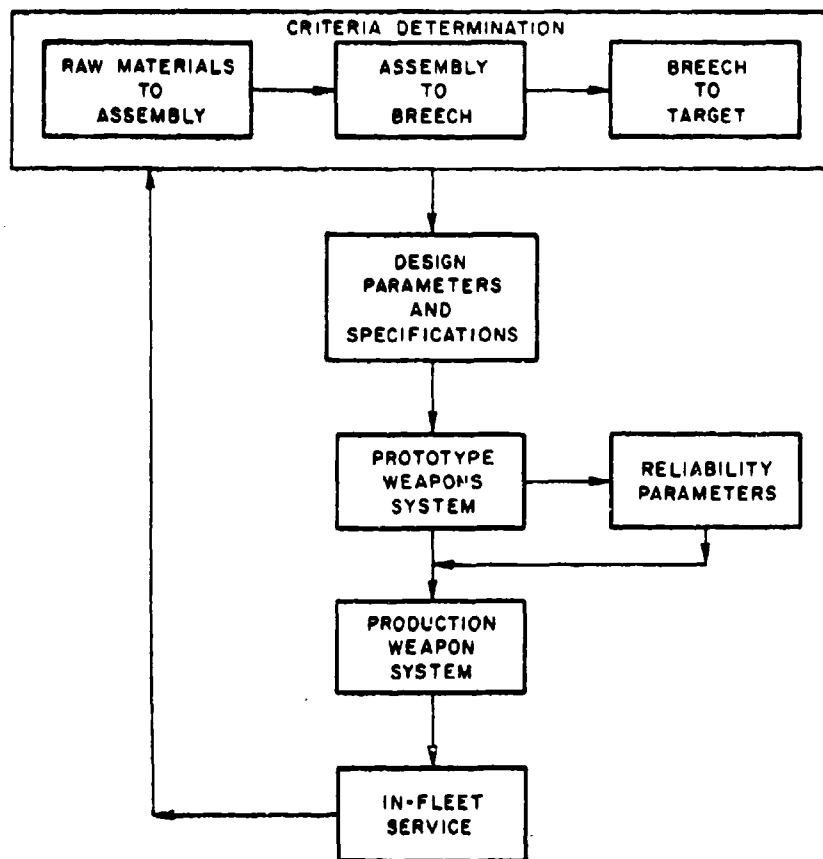


FIG. 5. Program Sequence.

The stockpile-to-target criteria sequence begins when the Government accepts the subassemblies from the manufacturers. Since the life of any weapons system is chiefly that of storage and transportation, the next part of the criteria determination should be concerned with only that portion of the weapon life. The weapon must be able to survive all intelligently assigned modes of service transportation and storage. The weapon, however, need not necessarily function during these segments but must be capable of functioning after appropriate conditioning by its using media. For example, a 5-inch Naval projectile may be dump stored in a desert depot, such as NAD, Hawthorne, Nevada. It must survive the desert summer temperature exposure but will not be fired until it is aboard a destroyer or other man-of-war. The temperature-of-firing extreme is not the same as that of desert dump storage.

When each criterion and storage or transportation mode is considered separately, the parts may then be intelligently combined to afford a test situation analogous to the in-Fleet situation. For example, in the past the high desert-induced temperature of 165°F has been combined with the high tropical or arctic relative humidity (RH) of 95%. A study of these situations shows conclusively that this condition cannot exist in nature. Elementary meteorological observations show that when the 165°F desert inclosed-air temperature is present, the RH is around 5 to 10%. The temperature extreme related to the tropical RH of 95% is usually no more than 85°F. (In the arctic, a 100% RH condition can be assumed to exist below 35°F.) Many weapons systems and components have been unnecessarily subjected to combined environmental testing that had no factual basis but was made an arbitrary requirement by the designer or specification writer who did not understand what the in-service situation actually would be. This has led to at least one instance where a \$100,000 instrument console was needlessly over-tested and subsequently ruined. An identical console later proved completely acceptable in service use.

The moment of truth is at hand when the weapon, still in working order after transportation and storage, is loaded and fired. In the case of a 5-inch projectile, the natural environments seem to be of much less importance in the short trip from gun barrel to target, and the induced environments take on much more vital significance. Setback shock, cross-axial acceleration, ramming shock, off-center wobble and spin-induced vibration are all relatively short lived, but, despite their short-time exertion, cannot be allowed to "dud" the round. Because of weapons system uniqueness, this portion of the stockpile-to-target sequence should be handled separately. By contrast, the stockpile-to-target sequence is probably identical for most shipboard-launched weapons. Once a good stockpile-to-target sequence is prepared and documented, it can be used by succeeding similar weapons systems, as long as the assumptions in both cases remain similar. Any breech-to-target sequence can serve only as a general guide for succeeding weapons systems.

A good stockpile-to-target sequence should be used as the basis for the weapons system design parameters. In most situations the numerical limits and conditions for the criterion should be the same in the stockpile-to-target sequence as in the "design to" specification. In the case of firing temperature, the designer is justified in "padding" the criteria determination values by a small percentage if this is deemed necessary. If it ensues that the extra percentage added is leading to development problems resulting in a vendor-requested waiver, the designer can safely grant the waiver back to his "preadded value" of the criteria determination without restricting the usage of the weapons system. In the present regime of specifications, the waiver is granted and a crash program is undertaken to determine if the weapons system has been jeopardized. Meanwhile development and/or production is usually halted until the "fix" is completed. The slowdown or shutdown of development usually is more costly than a reasonable criteria determination at the beginning of the program.

As soon as a prototype or preproduction unit is available, the design parameters should be confirmed by reliability tests. The specific piece of hardware must be subjected to the wide limits of all cogent criteria. The piece should be subjected until failure. The limits of the criterion withstood before failure by the actual hardware will give a good indication of adherence to design parameters by the vendor. This testing will expose both borderline designs and the possibility of expensive overdesign. In any case a better understanding of the actual ruggedness of the weapons system will be revealed. From this series of tests, the responsible designer can use engineering judgment as to any "fix" deemed necessary for a more efficient overall weapons system.

Continuing the data flow of Fig. 5, the results of the performance of a weapons system should be continually fed back into the stockpile-to-target sequence. Up to this time all environmental limitations have been based largely on a number of assumptions. When the weapons system is issued to the Fleet, the majority of the assumptions on which the stockpile-to-target sequence and the environmental criteria determination were based will be shown to be correct or incorrect. This information should be properly fed back so that the criteria determination can be perfected. Although it is too late for this particular weapons system, the information will be in a more usable form for any follow-on program. In this way a timely set of accredited and easily assimilated environmental documents will be established and maintained concurrent with the state-of-the-art.

The foregoing theories and conclusions are well intentioned and reasonably credible; however, the basic question is not answered. How can the designer preinsure the weapons system against failure while in Fleet service? The answer is contained neither here nor elsewhere at the moment. It is evident that if a new weapons system prototype could be released for Fleet evaluation while in the critical but flexible

design stage, a great deal would be learned and fed back into the formative phases of the project. The result would be an adequately designed weapons system containing all corrective measures normally associated with "after the fact" testing.

In reality there is never adequate time or funding to pursue the development of a weapons system in the Utopian manner suggested. Such paralleling of design activity concurrent with field tests would be the same as 1:1 analog testing. Since this idealistic approach is out of the question, the next logical step is to rationalize the relationships between the test variables with particular interest paid to the possible acceleration of the "aging processes". For example, a weapons system component exposed under the open sky would experience a constantly changing solar insolation from sunrise to sunset. The 1:1 analog test schedule would prescribe daily sunlight exposure for perhaps 2 weeks. Thermal equilibrium is the result of overnight exposure of the weapon. If the stabilizing time lapse between sunset and sunrise is assumed to be of no consequence, then it is practical to subject the weapon to continuous daytime heat cycles of 12 hours under laboratory simulated solar conditions for the required number of cycles. The analog becomes 2:1 under this arrangement. Now, if the mechanics of failure of the subject system (hardware oriented) tested is known, then an analog test of more condensed time scale can be devised. If a rocket motor propellant has a brittle temperature transition point that is temperature-cycle-sensitive for example, then the cycling through this temperature region will be a more useful test than elevating and maintaining the temperature for extended periods of time. The analog test in this case would be cycling from mean temperature to maximum temperature as quickly as the rocket motor mass could follow. Diversely, if the propellant is heat sensitive, causing energy loss due to elevated temperatures, more emphasis on the maximum temperature may be in order. In no circumstance should the 1:1 analog time scale be exceeded without specific justification.

Each field of weapons development must develop its own analog testing procedures. It should not be based on misuse of the analog situation, as most tests seem to be today, but on the basis of a firm, factual study of the environment in which the piece is ultimately expected to perform. When each field of study has explored the same problem from its own viewpoint, it may be seen that there are some specific approaches that are the same for most disciplines. Where these testing procedures are similar, or identical, one set of test parameters can be used, as long as the assumptions on which the tests are based do not change. Where the necessary test procedures do not conform to a preconceived set of test situations, new and specific test procedures must be developed.

An associated benefit of the definition of usable tests by each field of weapons development is the determination of the mathematical distribution of extreme situations. As it now stands, there is no hint to

the designer whether by using the MIL-STD series of documents he is designing to a probability of occurrence of 57, 90, or even 98%. The present information available usually does not indicate whether, for example, the -65°F test temperature will assure functioning under every conceivable situation, or whether that specific criterion is exceeded in the service life 43% of the time. The classifying of the present knowledge on a basis of the statisticians' normal distribution curve, if this is possible, will allow a designer a firm basis for deciding the advantage of spending a given amount of money to cover a greater percentage of possible occurrence. In this light, waivers can be examined as to the restrictive limitations placed on the completed weapons system. For example, no one knows positively whether the +120°F upper limit waiver on some surface-launched weapons system constitutes a restriction on its use.

As new data are collected, not only the extreme situation should be investigated but the average or mean situation should be investigated as well, so that the true life exposure of a weapons system can be presented. Too many designers accept "design to" temperature extremes of -65 and +165°F merely because these figures have never been subjected to a realistic "second look". A review of the specific theater of operation intended for the design project at hand will, in many cases, allow for less strenuous goals and result in less cost in all phases of the weapons system achievement.

The usage situation also has to be investigated from the standpoint of what normally happens, not what may possibly happen to one weapon in the complete span of usage for a given weapons system. A good design specification should reflect neither an overly pessimistic nor optimistic viewpoint. It should be emphasized that any design costs time and money. Since both are usually in short supply in the development of a new weapons system, they should be spent frugally. The foundation on which an economical development plan is based is a thorough knowledge of the expected life of that weapon. On this foundation, time and money will be spent for actual problem solution, not for imagined problems or non-analogous situations.

Appendix

LITERATURE SEARCH

As background to this type of work, a literature search was inaugurated to cover the environments for air-launched ordnance. The Technical Information Department (TID) Library at NWC was thoroughly searched for reports pertaining to tethered flight criteria for ordnance. The search revealed a total of 240 reports listed under the computer term "Environment". The term, "Tests, Environmental" totaled 322 reports. The sources of the Defense Documentation Center were searched along with ASTIA and the Prevention of Deterioration Center. Masses of report abstract cards were secured and carefully reviewed. The same result was found in all cases. The reports pertained to laboratory exposure of individual items ranging from resistors and capacitors to full-size ballistic rocketry to chamber testing as per a given MIL-STD or specific contractor specification. For criteria determination purposes these reports were of no value. They all presuppose the knowledge of the basic environment. The information given in the specification is assumed to be complete and correct. The basic information on which the specifications and standards are based is, in fact, very much open to question.

The combined literature search only brought to light information already known to the Environmental Criteria Determination Section of the Quality Assurance Division at NWC. There were a few surprises in that the search of TID report files unearthed references to earlier sources of some MIL-STD criteria than were earlier supposed but, in general, no new information was uncovered that would shed new light on environmental criterion.

Since the criteria was not found in the Navy literature system, the resources of the U. S. Army Test and Evaluation Command (TECOM) were utilized. The U. S. Army philosophy of environmental simulation dictates that any new piece of Army equipment from canned "C" rations to M-60 tanks must survive exposure to a season in the hot desert, cold arctic, and humid tropics. The mission of supplying these exposures falls to the U. S. Army Proving Ground, Yuma, Arizona, and the U. S. Army Tropical Test Center, Fort Clayton, Canal Zone, Panama. The meteorological data and support originates from the U. S. Army Electronic Research and Development Command, Fort Huachuca, Arizona. The test sites are Fort Greeley, outside of Fairbanks, Alaska, for the arctic; Yuma Proving Ground, Yuma, Arizona, for the desert; and Fort Clayton, Canal Zone, Panama, for the tropics. Since personnel from Yuma are primarily responsible for the reports and data submitted to the developmental agencies responsible for the inception and design of Army hardware, the reports on the performance of tested items can be found at the Yuma Proving Grounds and Aberdeen Proving Grounds, Maryland. A search of the Archives at the Yuma Proving Grounds revealed that the data in the reports

consisted primarily of "did the item function properly after exposure for a nonstandard time to an unknown environment". The Army philosophy is to expose the item to, for example, the cold arctic for any 15-, 30-, or 60-day period depending on number of projects, and personnel availability. After the exposure, whether it occurred during a cold snap, or a "warm" spell, the item is tested. If it functions successfully, it is given a clean bill of health. If it malfunctions, this also is reported.

The only data usually obtained that gives a clue to the exposure environment are meteorological. The "MET" team records all customary data to ascertain atmospheric conditions. Rarely, if ever, is any attention given to the actual temperature of the item tested. The meteorology is excellent, and can be obtained from the National Weather Records Center, Asheville, North Carolina, or in less formal form from Commanding Officer, Electronic Research and Development Command, Fort Huachuca, Arizona. These data have been found to be usable only as indicators of trends in ordnance exposure criteria. There are too many areas of missing information to rely on these data alone. The conclusion was reached that this line of endeavor was also virtually a dead end.

Previous to this assignment, the Environmental Criteria Determination Section at NWC had made contact with the then "Environmental Test Directorate" at the Wright Air Development Command, Wright-Patterson AFB, Dayton, Ohio. It is from the predecessors of this group that the majority of Military Specifications and testing documents have originated for all three military services. This organization developed the present MIL-E-5272C for the U. S. Air Force after World War II. They were also responsible for the replacement specification, MIL-STD-810. When questioned on the procedure used to establish criteria used in this series of documents, it was revealed verbally, and in October of 1965 in written form, that the majority of the information was "best guess", or based on very narrow measurements for limited purposes. The publication, "The Evolution of USAF Environmental Testing," by V. J. Junker, (Technical Report AFFDL-TR-65-197), is the most concise and comprehensive document covering this subject. Since the Navy relies so heavily on this family of specifications, it would be well if every Naval Air Systems Command engineer obtained and read a copy of Mr. Junker's report (Ref. 6).

The most usable data from Wright Field are centered around aircraft vibration. The preliminary work done in this area was to support the criterion found in MIL-STD-810. In essence they have obtained information for turboprop transports, jet bombers, Century Series jet fighters, and helicopters. These data are subdivided into various aircraft locations, such as "outer one-third of wing, inner two-thirds of wing, aft quarter of fuselage, forward quarter of fuselage, and center half of fuselage". Needless to say, all the information is on Air Force type aircraft, but the general levels are a good indication of energy levels to be found on Navy aircraft of the same general classification.

The contacts at Wright Air Development Command led to contacts at the U. S. Army, Natick Laboratories, Natick, Mass. The predecessors of the Natick Laboratories were responsible for the information used to write the worldwide extreme environmental specifications. The scientists at the then U. S. Army Quartermaster Research and Development Command were, in the majority, natural science types. An excellent job of collecting worldwide weather or meteorological extremes was done with the philosophy that these extremes are the limiting factors, not the design criteria for worldwide use items of Army issue (from a soldier's personal equipment to the large "engines of destruction"). When the work was done in the late 1940's and early 1950's, it was recognized as being the first step toward an integrated system of Military Specifications. The philosophy was to have as few MIL-STD documents as possible to preclude confusing the purchasing agent and contract administrator when a contract was assigned to industry. It must be remembered that, in this era, the complex weapon or weapon system was just starting to come off the drawing board. The propeller-driven aircraft and subsonic jet aircraft were still the first line of defense.

Presently, the Natick Laboratories, of the Army Material Command, have been working on worldwide analogues for the major test stations and proving grounds in the U. S. Army Test and Evaluation Command. For example, the weapon that survives and functions at Yuma Proving Grounds is good for use in the Punjabi Desert, the African Desert, etc. From these worldwide analogues it is possible to obtain an exposure analogue of deserts in the United States or any other desert area. This in itself does not answer environmental exposure questions but it does reinforce the usefulness of any environmental exposure information conducted in the Continental United States.

The above installations constitute the sources of the vast bulk of the environmental literature. There are others, such as North American Aviation and McDonnell-Douglas Aircraft, who have contributed parts to the literature. However, the pieces of environmental information that come from the contractors are filed in the library of one of the TECOM or WADC installations. On the whole, the reports from contractors consist of "what happened to a specific resistor" while subjected to MIL-E-5272C type of testing and not "what will Fleet usage require".

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Part 3 defines each environment treated in the stockpile-to-target sequence (Part 1) in general terms. It presents a frame of reference in which the total environment can be discussed by test engineer, designer, and project manager without a communication breakdown due to different interpretations of the subject matter.		

DD FORM 1473

(PAGE 1)

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DD FORM 1473 (BACK)
 (PAGE 2)

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